Steady State Gyrokinetic Transport Project

NCCS USERS MEETING

Mark Fahey, ORNL

March 27-29, 2007

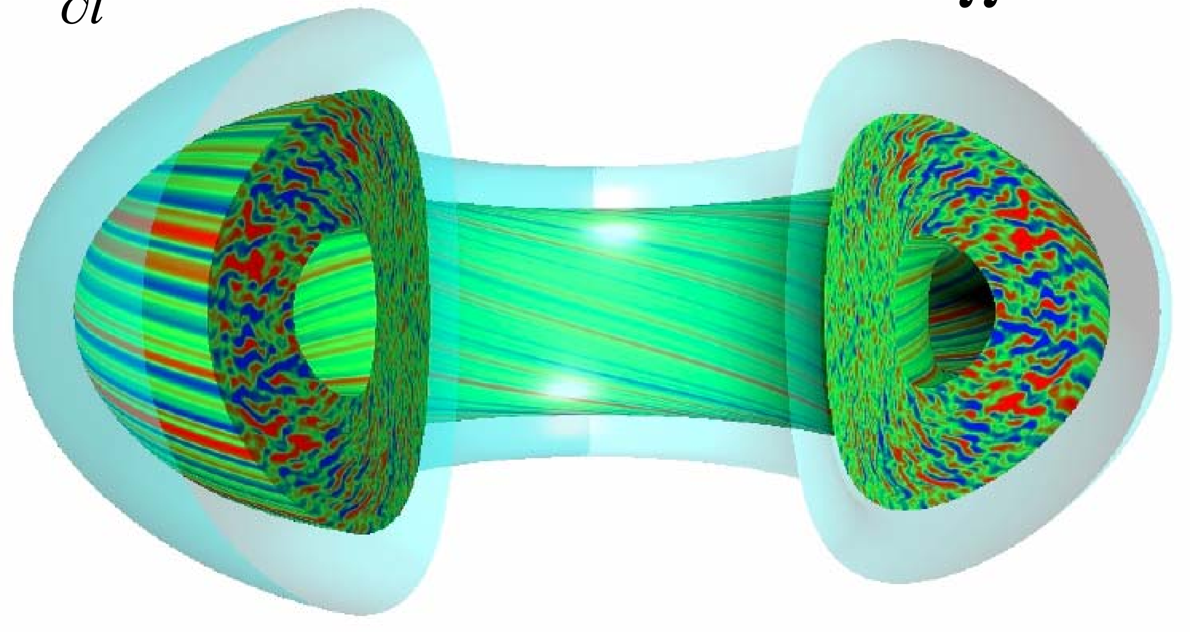
Project Overview

- **Project Participants**
  - Jeff Candy (PI), General Atomics
  - Mark Fahey, ORNL
  - Ron Waltz, General Atomics
- **Project Summary**
  - Develop a prototypical steady-state gyrokinetic transport (SSGKT) code that integrates micro-scale gyrokinetic turbulence simulations into a framework for practical multi-scale simulation of the International Thermonuclear Experimental Reactor (ITER).
  - Companion to the SciDAC-II project of the same name.
  - The **GYRO** microturbulence code will be the main building block
- **Project Milestones**
  - Determine an efficient feedback algorithm during code development, because outputs are intermittent and extremely expensive
  - Demonstrate that gyrokinetic codes can be run practically within a transport code
  - Perform predictive fixed-flux simulations for ITER on transport timescales

GYRO

- A 5-D gyrokinetic-Maxwell solver which computes the radial transport of particles and energy in tokamaks plasmas
- Employs an Implicit-Explicit Runge-Kutta scheme discretized on Eulerian grid

$$\frac{\partial f}{\partial t} = L_a f + L_b \Phi + \{f, \Phi\} \text{ where } F\Phi = \iint dv_1 dv_2 f$$



Project impact

- **What can be solved from the results?**
  - The prototype will have the capability to predict steady-state core temperature and density profiles given the H-mode pedestal boundary conditions.
- **Who cares about this work and its results? Why?**
  - This addresses a key problem of critical scientific importance; namely predicting the performance of ITER given an edge boundary condition.
  - Demonstrating that gyrokinetic codes (simulating micro-scales) can be run practically within a transport code (simulating the macro-scale) is referred to as *simulation of turbulence on transport timescales*[1]

[1] One of the four leading Focused Integration Initiatives for a Fusion Simulation Project [Fusion Energy Sciences Advisory Committee (FESAC): *Dahlburg Committee Report* (2002); http://www.isofs.info]

Project logistics

- **What size production jobs will you be running?**
  - Some developmental runs with several hundred
  - Interesting physical runs with ~5000 processes
- **Do you have any special requirements (software/libraries/data storage/scientific workflow)?**
  - Libraries: FFTW (or vendor FFT), MUMPS
- **Do you have any special visualization needs?**
  - No

Project logistics (continued)

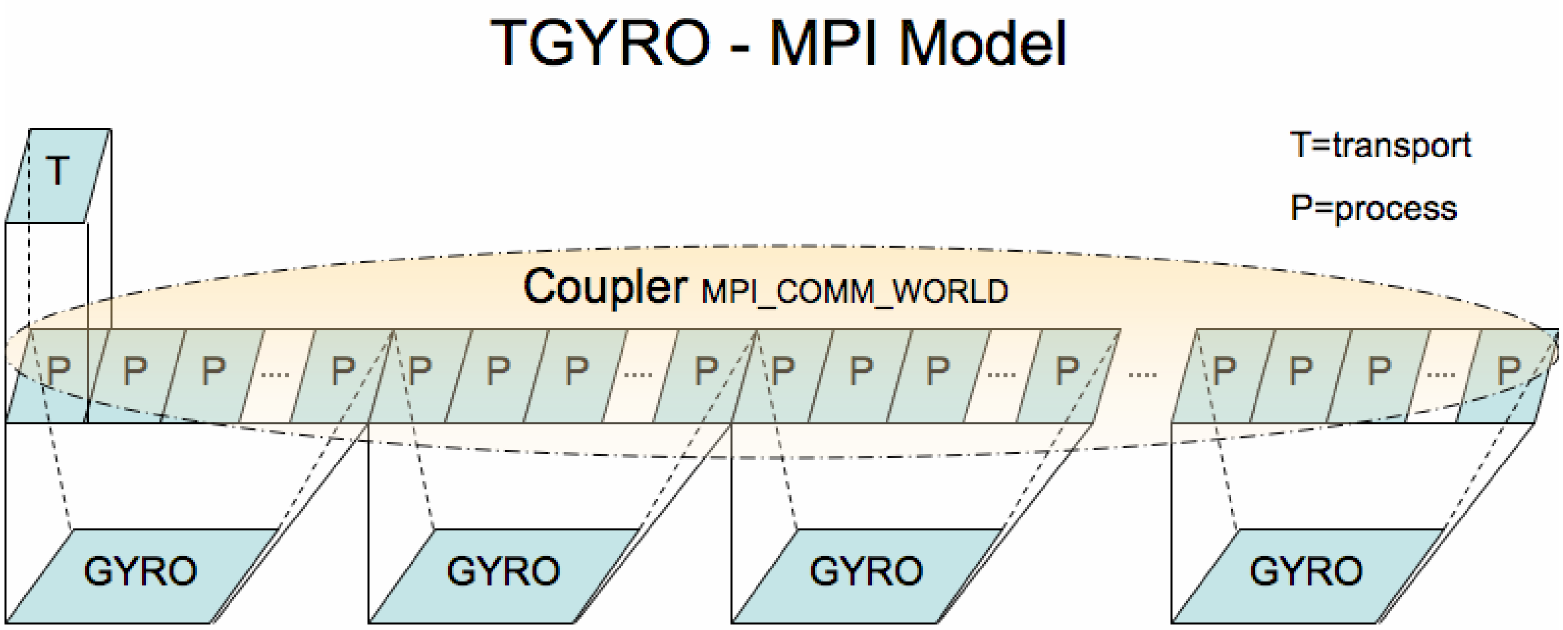
- **What development efforts are required?**
  - By separating the turbulence (internal, micro-scale physics) and transport (external, macro-scale physics) time scales, and introducing a feedback loop between them, one can arrive at the steady-state transport balance required for a true macro-scale steady-state solution. We are developing a master coupler code to coordinate and provide feedback between a transport code and multiple separate GYRO simulations.
  - Each instance of GYRO will compute local radial fluxes that will be periodically communicated to the master. In comparison to the size of a local simulation distribution function, the amount of data to be communicated to the master will be minimal.
  - We have a working prototype today, without the transport piece. We need to develop the transport functionality. But we will continue to improve the coupler code, and in particular to define interfaces between the various components. And the particular feedback scheme will also be under continuous refinement.

Project logistics (continued)

- **What issues/problems do you anticipate as you begin production?**
  - Designing the feedback scheme
  - The code coupling is fairly straightforward and proceeding nicely
- **What level of interaction do you anticipate with the NCCS staff?**
  - Mark Fahey is part of the project team
  - No other NCCS staff interactions are expected

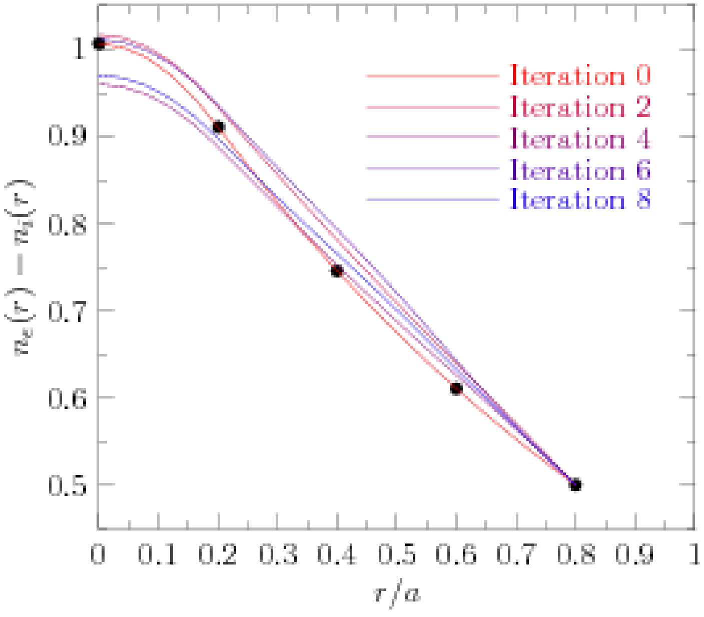
Development Status

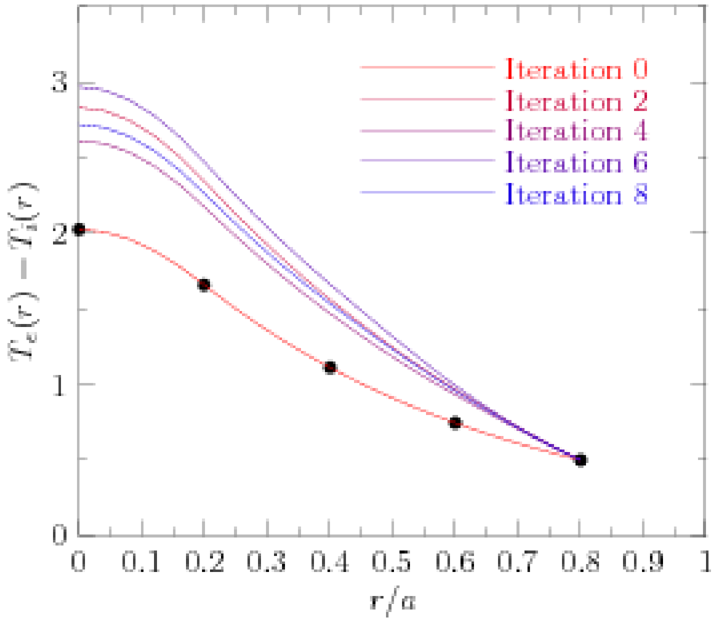
- **Have a working prototype, called TGYRO**
  - Parallel model will look like the figure
  - As of today, we don't have the transport functionality



Development Status (cont.)

- **Preliminary results of a 4 radial node test**
  - Multiple GYRO simulations are iterated (input parameters adjusted) to bring them into flux “balance” (production balances turbulent loss) with thermonuclear production
  - Each node represents a gyro run with 16 processors
  - As far as we know, first example of a steady-state profile prediction from a gyrokinetic code
  - Obtained steady-state density and temperature profiles





Development Status (cont.)

- **Next steps**
  1. Refine interfaces and structure
  2. Implement global transport solver
  3. Add physics module to calculate the target power
  4. Study the (local) iteration scheme more carefully

– **Will require long-running, large-scale testing**